Total Dissolved Gas Measurements Downstream of Wickiup Dam on August 27, 2013

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Introduction

At the request of Biota Pacific, CH2M HILL obtained total dissolved gas (TDG) measurements at several sites in the Deschutes River between the tailrace of Wickiup Dam and Pringle Falls Campground. This memorandum describes the methods and results of the TDG measurements.

Methods

TDG measurements were taken at each site using a portable In-Situ Tensiometer 300E (as described further below). Additional measurements of water temperature, dissolved oxygen (DO), and barometric pressure (BP) were taken at each site using a portable Thermo Scientific Orion Three-Star water quality probe (as described further below). The resolution and accuracy of the probes are listed in Table 1.

All measurements were taken on August 27, 2013 between 11:30 AM to 3:00 PM. The probes were held into the water from shore using a 3-meter (m) extension pole to a sampling depth of about 0.1 to 0.5 m. The probes were periodically agitated over a period of 10-15 minutes to ensure that stable, equilibrated readings of TDG were obtained. The probes were successfully calibrated prior to the field visit and again in the field according to manufacturer instructions and specifications.

TABLE 1
Resolution and Accuracy of the Probes

Parameter	Probe	Resolution & Accuracy
Differential Gas Pressure (ΔP)	Tensiometer 300E	Resolution: 1 mm Hg Accuracy: ± 1 mm Hg over operating temperature range of 0°C to +45°C
Water temperature	Orion Three-Star	Resolution: 0.1°C; Accuracy: ± 0.1°C:
Dissolved oxygen (DO)	Orion Three-Star	Resolution: 0.01 mg/L; Accuracy: ± 0.1 mg/L up to 8 mg/L; ± 0.2 mg/L from 8 mg/L to 20 mg/L
Barometric pressure (BP)	Orion Three-Star	Resolution: 1 mm Hg; Accuracy: ± 6 mm Hg

Tensiometer 300E

The Tensiometer 300E is a compact field instrument that checks for supersaturation by measuring the total pressure of all gases dissolved in water—nitrogen, oxygen, carbon dioxide, argon, and so forth.

Supersaturation is the condition that exists when the TDG pressure in water is greater than the atmospheric pressure at the surface of the water.

The 300E consists of a probe with a 5-meter cable, and a digital meter. The probe consists of a precision pressure transducer, conditioning electronics, and a membrane cartridge. The membrane cartridge consists of a sensing membrane—approximately 1.5 meters of very small bore silicone tubing. One end of the tube is sealed, the other end is connected to the pressure transducer which converts the internal tube pressure to an electrical signal. The tube is permeable to all gases including water vapor. The digital meter conditions and amplifies the transducer output, which is then indicated on a 3-digit liquid crystal display in millimeters of mercury (mm Hg).

When the probe is immersed in water, gases effuse through the tubing wall until the gas pressure inside the tube is equal to the gas pressure outside the tube. This condition is called equilibrium and when reached, the 300E displays the TDG pressure in the water, commonly referred to as Differential Gas Pressure (ΔP), in millimeters of mercury (mm Hg). Differential Gas Pressure is defined as the difference between the atmospheric pressure at the surface of the water and the sum of all the partial pressures of the gases, including water vapor, dissolved in the water. A positive ΔP indicates that the water is supersaturated, and a negative ΔP indicates the water is subsaturated.

ΔP (mm Hg) is the standard reporting unit of the 300E probe. The ΔP was converted into units of percent-saturation (% Sat) using a gas calculator spreadsheet provided by the manufacturer. These calculations are based on the dissolved gas computational methods of Colt (1984) as related to natural waters and aquaculture applications.

Orion Three-Star Probe

Additional measurements of water temperature, DO, and barometric pressure were taken using the portable Orion Three-Star water quality probe. The probe uses the latest RDO optical technology for measuring DO, which is easy to calibrate and maintain, and provides stable and accurate results. When the probe initiates a reading, a blue LED emits blue light, which excites lumiphore molecules in the sensing element. Excited lumiphore molecules emit red light, which is detected by a photodiode. Oxygen molecules quench the excited lumiphore molecules and prevent the emission of red light—a process called “dynamic luminescence quenching.” Determination of DO concentration by luminescence quenching has a linear response over a range of concentrations.

The Orion Three-Star probe has an internal thermistor (for measuring water temperature) and barometer (for measuring barometric pressure) that are used for pressure compensated DO readings. This allows the unit to provide a read-out of percent-saturation of DO. Percent-saturation of DO is the amount of DO in the water sample compared to the maximum amount of DO that could be present. For example, as water temperature increases, the DO concentration (in mg/L) at 100 percent saturation decreases; that is, cold water can hold more oxygen than warm water. Also, the greater the atmospheric (barometric) pressure, the more oxygen the water will hold. DO percent saturation values of around 100 percent are typically expected in well-mixed, high-quality rivers and streams.

Results

TDG, water temperature, DO, and barometric pressure measurements were obtained at six sites in the Deschutes River between the tailrace of Wickiup Dam and Pringle Falls Campground. The six sites are shown in Figure 1 and the values obtained from the measurements are listed in Table 2. Table 2 also includes computations of percent saturation of TDG, and the component values of percentage-saturation of oxygen (O2) and nitrogen (N2) as calculated based on the computational methods of Colt (1984).

During the time of the measurements, the river flow was 1,390 cfs and the water temperature was 14.7°C as measured at the Hydromet gage located about 200 m below Wickiup Dam (WICO: Deschutes River below Wickiup Dam, OR).

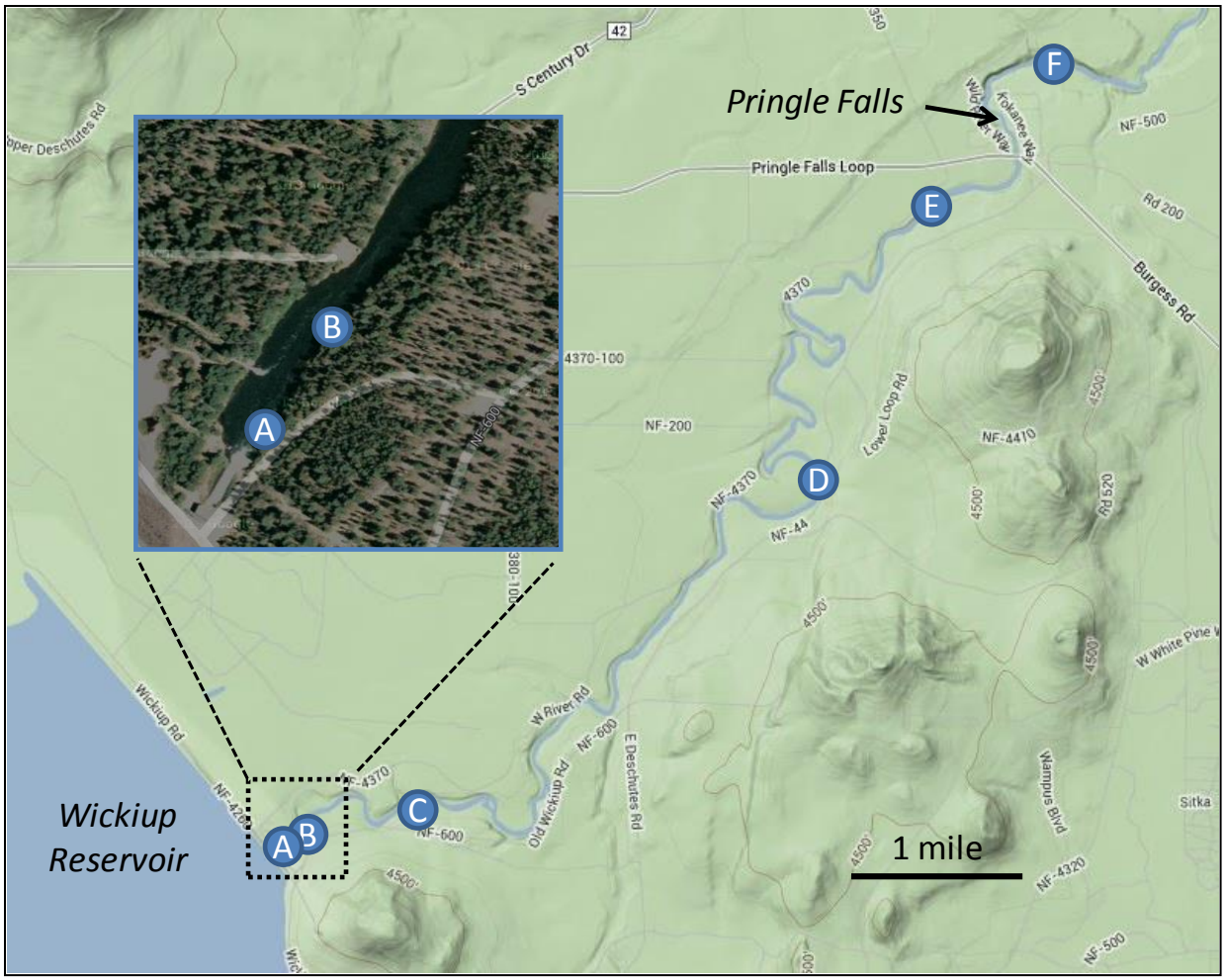

FIGURE 1
Sampling sites in the Deschutes River between the tailrace of Wickiup Dam and Pringle Falls Campground.

TABLE 2
Values of Measurements Downstream of Wickiup Dam on August 27, 2013

Map Letter	Site Name	Time	Water Temp (°C)	BP (mmHg)	ΔP (mmHg)	DO (mg/L)	O2 (% Sat)	N2 (% Sat)	TDG (% Sat)
A	Just below Wickiup Dam tailrace	13:20	14.6	651	44	9.6	111	106	107
B	150 m below Wickiup Dam tailrace	13:45	14.6	651	53	9.9	114	107	108
C	At Tenino Boat Ramp	12:50	14.6	651	46	9.9	114	106	107
D	Between Tenino and Wyeth	12:20	15.2	652	44	10.2	119	104	107
E	At Wyeth CG	11:30	15.4	653	43	10.0	116	104	107
F	At Pringle Falls CG	14:40	16.4	652	34	9.5	113	103	105

Discussion

The results indicate that TDG was supersaturated (greater than 100 percent saturation) at all sites during this sampling event. All values fell within a fairly narrow percent-saturation range (105-108 percent), with the highest value occurring 150 m below Wickiup Dam and the lowest value downstream at the Pringle Falls camp ground. The lowest value below Pringle Falls suggests that dissolved gas supersaturation was gradually dissipating toward an atmospheric-equilibrated saturation level (that is, 100 percent) as flows travelled downstream.

None of the recorded values exceeded the numeric portion of the State TDG standard (OAR 340-041-0031). The numeric portion of the standard states that the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 110 percent of saturation. As such, the levels of TDG represented by the measured values are not likely to cause significant adverse effects on aquatic organisms.[1]

DEQ (2011) reports that TDG supersaturation has been previously observed on the Deschutes River below Wickiup Dam. For example, TDG levels ranged from 109 to 115 percent saturation in samples collected by USBR below Wickiup Dam in July sampling events in 1995, 2001, 2004 and 2007 (DEQ 2011). The effects of dam operation on TDG have been well-documented (e.g., Colt et al. 1986, Weitkamp and Katz 1980). Gas supersaturation below dams occurs during spillage when air becomes entrained in the water column and is forced into solution. Bouck (1976) reports that TDG supersaturation also may occur naturally in streams for other possible reasons, including gas entrainment from high stream velocity and waterfalls, DO supersaturation from algal photosynthesis, increased gas saturation due to changes in solar or seasonal heating of lakes and reservoirs, and gas dissolution in contributing groundwater that has been geothermally heated.

Of these reasons, gas entrainment from dam spillage and DO supersaturation from algal photosynthesis in the reservoir could be the primary explanatory factors in this case. DEQ (2011) reports that there appears to be a relationship between Wickiup Reservoir spillage outflow and TDG saturation with TDG levels increasing with flow. Also, DO supersaturation values of 111 to 119 percent were recorded at all sites during this sampling event (Table 2). Similar DO supersaturation has been reported at many locations in the Deschutes Basin as a result of high primary productivity (i.e., algal photosynthesis), which results in higher oxygen concentrations than would otherwise occur in waters at that particular temperature and elevation (Jones 2003, Davis and Kunkel 2010). Wickiup Reservoir has substantial blooms of algae (phytoplankton), particularly during the summer months (Atlas of Oregon Lakes; http://aol.research.pdx.edu/).

References

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Colt, J. 1984. Reprinted 2002. Computation of Dissolved Gas Concentrations in Water as Functions of Temperature, Salinity, and Pressure. A handbook of equations and data for aquaculturists, physiologists, power-plant operators, river managers, and anyone concerned with gas concentrations and supersaturation. Special Publication 14 of the American Fisheries Society.

[1] Based on an extensive review of the scientific literature assessing the biological effects of TDG supersaturation on aquatic organisms, a group representing the U. S. Environmental Protection Agency (USEPA) and state regulatory agencies of Washington, Oregon, and Idaho in the late 1970s concluded a level of 115 percent saturation could be tolerated by juvenile salmonid fishes, considering the compensatory effects of hydrostatic pressure (Rulifson and Pine 1976). When compensating water depths are available, TDG levels up to 120 percent for short-term periods do not produce significant adverse effects on juvenile and adults salmonid fishes (Johnson et al. 2005). The general consensus at the time was a TDG level of 115 percent could serve as a criterion for the protection of juvenile salmonid fishes from direct lethal effects. However, the group recommended a lower level of 110 percent be adopted as the water quality standard for the protection of shallow-water macroinvertebrate species, which are important food chain organisms (Rulifson and Pine 1976). As a result, the 110 percent value was established by the USEPA as a biological criterion and adopted by ODEQ as a water quality standard. The standard continues to exist today.

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